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CORRELATIONS BETWEEN REMOTELY MEASURED SOIL WATER CONTENT AND SURFACE TEMPERATURES FOR THE BEAUCE REGION, FRANCE

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1. INTRODUCTION

Soil water content has been shown to be highly correlated with radiometric surface temperatures, and a number of studies have demonstrated that the surface temperature increases as the substrate soil water content decreases. (See Hatfield et al. (1983) and Carlson (1984) for a summary of articles on this research.) As part of a study to model the available water in the unsaturated zone using thermal infrared data, this paper is a first look at some aircraft measurements that show a correlation between microwave measured soil water content and radiometric surface temperatures.

During an experiment held in the summer of 1983 near Voves, France, active microwave and thermal infrared measuraments were made during the early afternoon aboard a French aircraft flying a grid pattern over a flat, agricultural region south of Paris called the Beauce. The vegetation consisted mainly of wheat and corn, with some stands of trees. The infrared sensor was a Barnes PRT-5 radiometer which has a measurement accuracy to within .5 degrees celsius. The active microwave measurements were taken with the ERASME scatterometer (5.35 GHz (FM-CW) with an incidence angle of eleven degrees for minimizing the effects of roughness and therefore maximizing the accuracy of soil water measurement. Calibration missions of the microwave measurements were performed with reference to in-situ measurements of soil water content; the correlation coefficient was .89 between the microwave back scatter coefficients and the ground measurements of the soil water content in the first ten centimeters. Accordingly, soil water content was converted directly from backscattering cross section to soil water content. The scatterometer and radiometer were mounted so that the two instraments were taking measurements of the same ground area simultaneously, five measurements per second, with each having a surface sampling area of approximately 40 meters squared. The average flight altitude was about 400 meters.

Data was collected during July and September of 1983; the dates in July were 8 and 12 July during a period of drying following a 6 July rainfall episode; the September dates were the 20, 23, 26, 28 and 29 September following a 19 September rainfall episode. Data segments along two of the aircraft legs were selected to discuss because they represent alternately the poorest and best correlation of surface temperatures with microwave-derived soil water content measurements, respectively on 8 July (1:45 LT) and 26 September (3:45 LT).

To examine the data through time and perform some descriptive statistics, a statistics/graphics package (SAS) was used to plot the microwave and thermal IR data, and to perform correlations between them. Figure 1 shows a plot of the temperature resonse as the sensor was flown over a west to east transect near the town of Voves on 8 July. Figure 2 shows a plot of the soil moisture values measured along the same transect. In order to gain a simple visual comparison between the temperature and microwave measurements, the two lines are overlain on the same plot, using a cubic spline to fit the points (see figure 3). Note the inverse relation between the microwave backscatter and the surface temperature at the points where the sensor was flown over road surfaces (A, B, D, L, M, N on figure 3) which are very dry and have a high surface temperature. Figure 4 is a transect flown on 26 September, over approximately the same area as in figure 3. Note that for the same roads (points B, D, L, M), the data again show that a low soil water content correlates with a high surface temperature. However, for the 26 September case, this inverse relation is demonstrated over the entire transect. For both of the cases, the subset area labelled on figures 3 and 4 were plotted to show the variations of the microwave and thermal infrared response on a field basis (see figures 5 and 6).

2. RESULTS AND DISCUSSION

The first and most important observation is the poor correlation between the microwave backscatter coefficients and the thermal infrared measured temperatures for the 8 July case (shown in figure 3). The correlation coefficient for the entire data segment is .3459. The correlation between these same data types is -.7795 for the 26 September case, which is what would be expected given previous research. Possible explainations (not yet confirmed) for this lack of correlation of the vegetated 8 July case are:

i) For the July case, the plants may be in effect "integrating" the available water because they are using the water at depth (in the root zone). If the surface temperature was being influenced by the amount of water available at a depth of perhaps 45 cm or more, and the variability of this soil water content is not as great as that at 0-10 cm (being measured by the microwave), there would be a difference in the variability of the surface temperature and the microwave measurements. This difference in variability could decrease the correlation between the remotely measured temperature and soil moisture for any given point.

ii) There could be a difference in the "measurement depths" between the July and September cases. For the July case, the thermal infrared sensor is measuring temperatures that are largely influenced by the water available to the plants in the root zone (much deeper than 10 cm), while the microwave backscatter coefficients are most highly correlated with the top ten centimeters. For the September case, with nearly bare soil conditions, the thermal infrared temperatures are more influenced by the soil water content near the surface, and the microwave backscatter coefficients are again most correlated with the soil water content in the first ten centimeters.

iii) If the stomates were closed for some reason other than lack of available water, the plant temperatures measured by the thermal infrared sensor could be much higher that what would be expected for a given soil water content.

Another observation is the possible lack of a significant correlation between remotely measured soil water content and surface temperatures within an individual field. For one corn field (field 10) there is a correlation coeffient of -.326 for 8 July and -.484 for 26 September. For the forest stand (field 7), the correlations are +.403 for 8 July and -.18 for 26 September (see Table I).

Finally, it can be seen from figures 5 and 6 that there is a greater variation of microwave backscatter coeffiecients than surface temperature . This would tend to support the idea that the variability of soil moisture is greater in the surface layers of the soil.

Table 1. CORRELATION COEFFICIENTS BETWEEN TEMPERATURE AND SOIL MOISTURE

DATE	FIELD COVER	SURFACE TEMPERATURE	MICROWAVE	N	CORREL.
8 July	all data (mixed cover)	29.7 +/- 1.98	-2.10 +/- 2.26	9165	-.004
	segment 3 (mixed)	30.1 +/- 1.98	-1.87 +/- 1.77	1004	.346
	segment 3 subset (mixed cover)	30.4 +/- 1.15	-.660 +/- 1.52	218	-.170
	field 10 (corn)	29.1 +/- .308	-.051 +/- .984	68	-.326
	field 7 (woods)	29.2 +/- 1.07	-2.80 +/- 1.23	29	.403
26 Sept.	all data (mixed cover)	31.3 +/- 2.79	-3.98 +/- 2.82	7556	-.712
	segment 3 (mixed)	31.4 +/- 3.02	-3.15 +/- 2.82	926	-.780
	segment 3 subset (mixed cover)	30.8 +/- 2.92	-2.94 +/- 2.69	232	-.722
	field 10 (stubble)	26.8 +/- .537	.258 +/- .755	73	-.484
	field 7 (woods)	32.4 +/- .538	-4.61 +/- .642	24	-.181

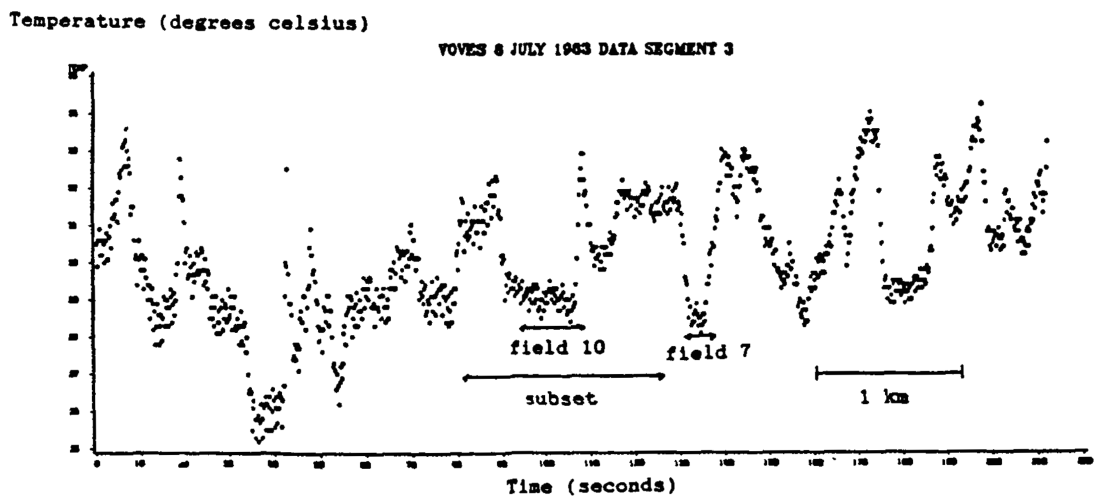

Figure 1. West to east tranverse showing the thermal infrared response. Time of day approximately 1:45 LT Note locations of fields 10 and 7, and the location of the subset to be examined later.

Temperature (degrees celsius) - - - - -
Soil water content (cm**3/cm**3 x 10**2) ————

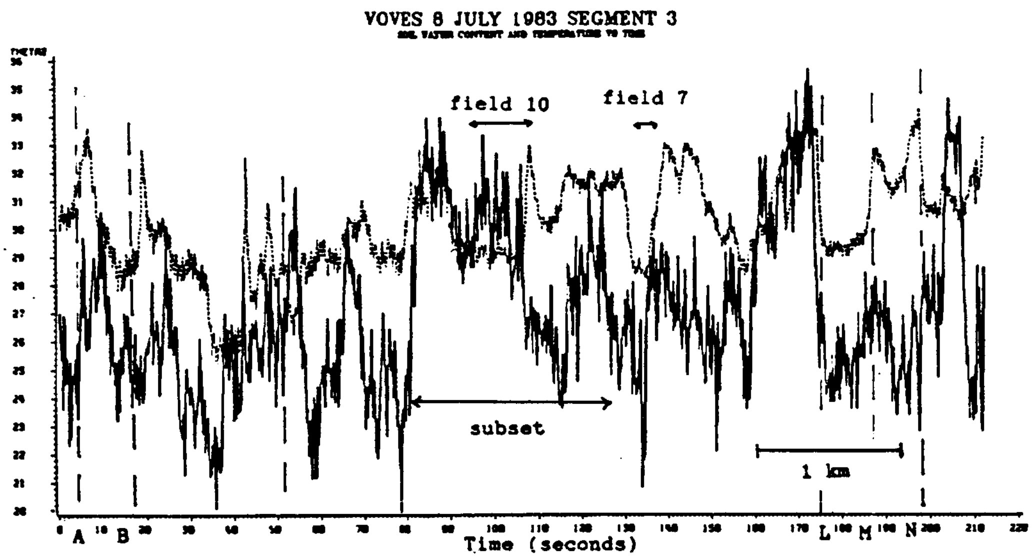

Figure 3. Combined plot for soil water content and temperature. Note the inverse relation of the responses for roads (points A,B,D,L,M,N).

Soil water content (cm**3/cm**3)

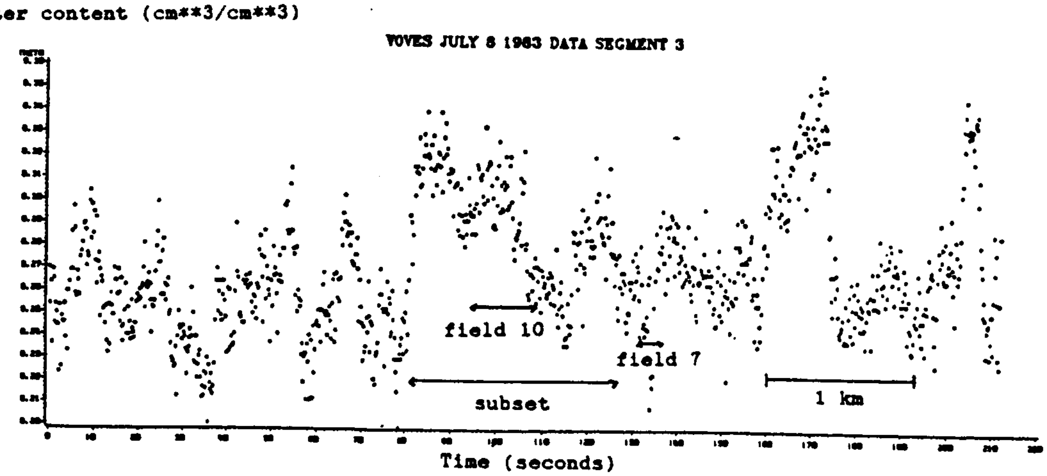

Figure 2. Soil water content measured with active microwave, same transverse as in figure 1.

Temperature (degrees celsius) - - - - - - -

Soil water content (cm**3/cm**3 x 10**2) ————

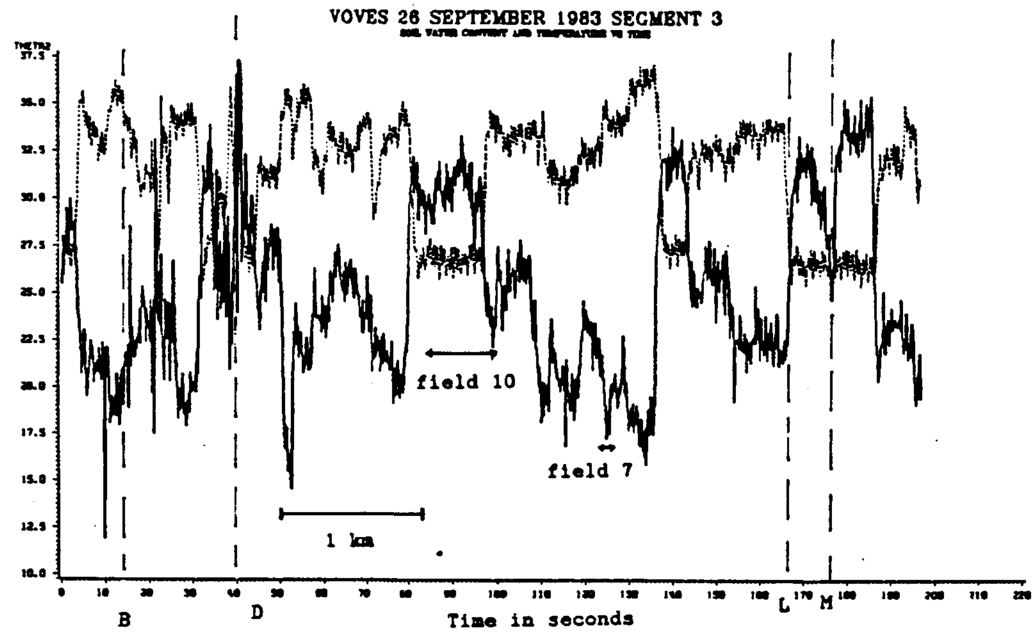

Figure 4. Combined remotely measured soil water content and surface temperature for approximately the same transect as in figure 3, ' data taken on 26 September at approximately 3:45. Note the inverse relation of the microwave and temperature responses. The road locations are the same as in figure 3.

Temperature (degrees celsius) - - - -

Soil water content (cm**3/cm**3) ————

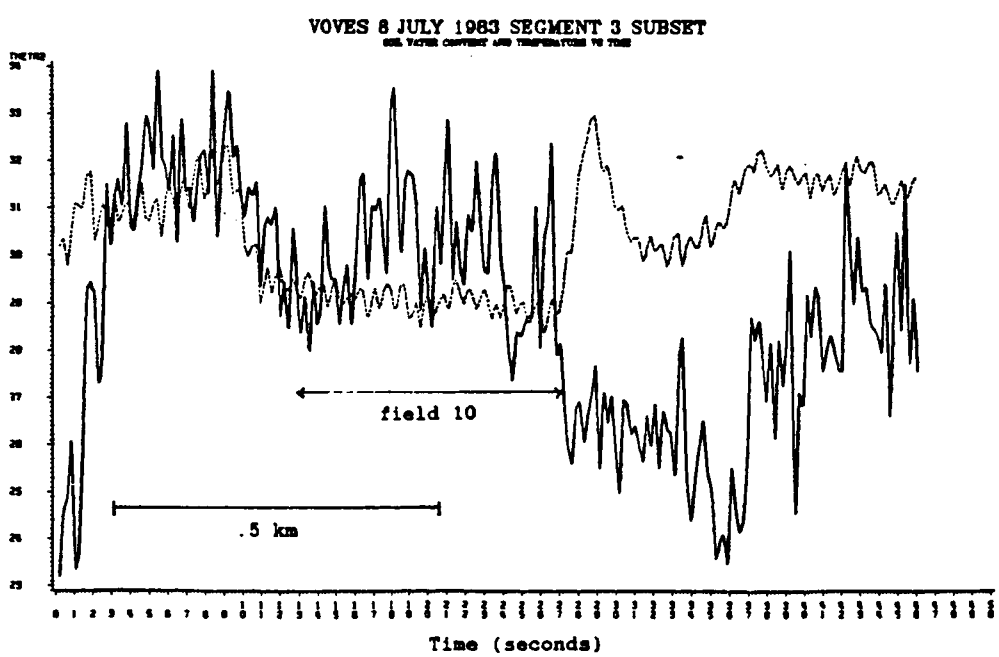

Figure 5. Combined temperature and soil water content responses for the subset of data segment 3. Note that the variation for soil water content within a field is much greater than the variation of temperature.

Temperature (degrees celsius) - - - - -

Soil water content (cm**3/cm**3) ———

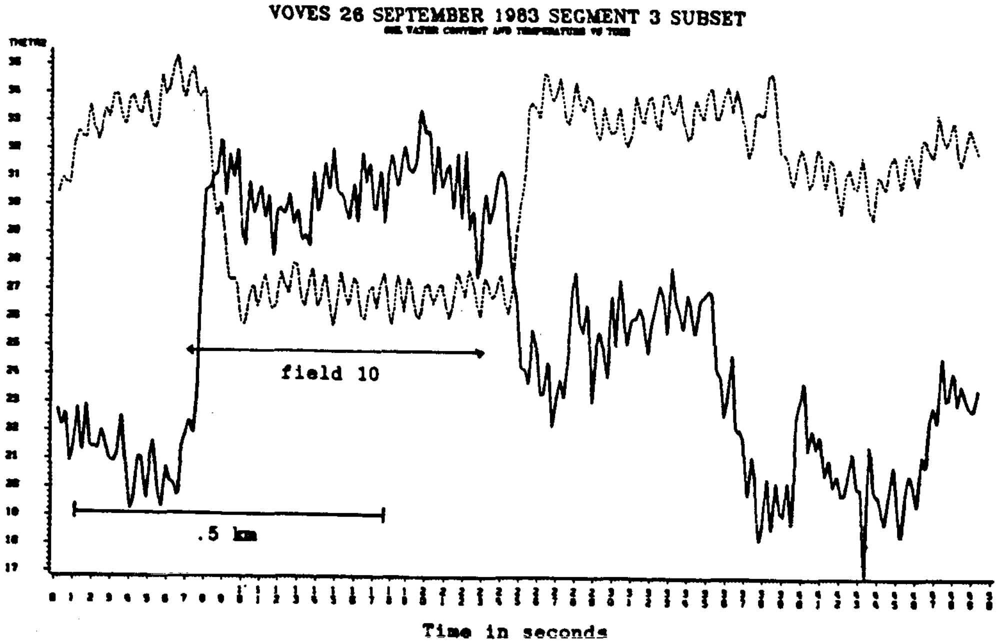

Figure 6. Combined temperature and soil water content for the subset of data segment 3, for the 26 September case. Note again the greater variability of the soil water content measured by the microwave.

3. CONCLUSION

The data analyzed so far has indicated a strong negative correlation between remotely sensed soil water content and surface temperatures for the near bare soil conditions of 26 September, while for the same area on 8 July there is little correlation between the remotely sensed soil water content and surface temperature.

4. REFERENCES

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